ATMOSPHERIC FORCING OF OCEAN CONVECTION IN THE LABRADOR SEA

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LONG TERM GOAL

The long term goal of this research is to understand the relation between atmospheric forcing and ocean deep convection.

OBJECTIVES

1. The primary objective is to use ocean numerical models, remotely-sensed information and *in situ* ocean data, to examine the sensitivity of the ocean to various atmospheric forcing specifications, the latter based on Objective 2-4 results. Try to understand the physics involved in the relationship between the atmosphere and deep convection.
2. Quantify the atmospheric forcing (heat flux, salt flux, momentum flux) for the entire Labrador Sea during the period of the 1997 *R/V Knorr* cruise using a combination of in situ, model, aircraft and remotely-sensed data.
3. Evaluate the accuracy of research (COAMPS) as well as operational numerical forecast models (NOGAPS, NWS products, ECMRF) in providing atmospheric forcing fields in the Labrador Sea during winter.

APPROACH

These objectives require collaborations with other researchers involved in the Labrador Sea Deep Convection Experiment (LSDCE) and other projects. The PI will accomplish Objective 1 by comparing atmospheric forcing fields, determined as a result of Objectives 2-4, with ocean conductivity, temperature and depth (CTD) profiles, with ocean float and drifter data and numerical ocean models. The response of the ocean to the atmospheric forcing will be analyzed by statistical analyses of real data from the experiment phase of the LSDCE. The CTD data will identify changes in the ocean thermodynamic structure on times scales of weeks and months. The float data will provide information on the ocean dynamics and will allow the examination of the short term dynamic response of the ocean to measured variations in atmospheric forcing. We hope to answer the following questions:

1. How do the actual "spin-up" and "relaxation" time scales for the response of the ocean convection to changes in atmospheric forcing compare with theoretical predictions?

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2. How important are mesoscale ocean features in controlling deep convection and what is their relationship to the atmosphere?
3. Are there critical atmospheric parameters required to predict and understand deep convection and if so what are they?
4. Are the model results that individual storms do not have much lasting effect on the structure of the upper ocean in the Labrador Sea confirmed by observations?.

Objectives 2-3 are required to quantify the atmospheric forcing. Objective 2 involves collaboration with scientists from the Bedford Institute of Oceanography who performed turbulence measurements during the 1997 LSDCE *Knorr* cruise. We will determine ship flow distortion effects using a numerical model. We will quantify the sensible heat and momentum fluxes using the inertial-dissipation method. These point measurements will be extrapolated to the rest of the Labrador Sea using the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) developed at the Naval Research Laboratory. Objective 3 will involve a comparison of the fluxes as determined by the ship with COAMPS predictions in order to assess the suitability of using COAMPS to determine forcing fields in the wintertime Labrador Sea. Because the structure of the atmospheric boundary layer (ABL) has a large effect on the spatial characteristics of the surface fluxes, we will also compare the temperature, humidity and depth of the ABL as predicted by COAMPS with direct *in situ* rawinsonde measurements.

ACCOMPLISHMENTS

During the 1997 winter cruise of the *Knorr*, the PI and colleagues successfully performed 217 rawinsonde (weather balloon) soundings of the atmosphere. These represent the only rawinsonde measurements ever performed in the central part of Labrador Sea. This information is crucial to understanding how the atmosphere forces the ocean. The PI also completed a successful radiation measurement program. The PI assisted in measurements of standard meteorological parameters (winds, temperature, humidity, pressure, precipitation) as well as turbulent wind and temperature parameters. Because the direct turbulence measurements are not yet processed to determine surface fluxes, the PI estimated the turbulent fluxes using a bulk method. Net radiation was determined from the direct measurements of downwelling radiation and estimates of upwelling radiation based on surface conditions (i.e. surface temperature and albedo). These measured and derived quantities represented all the terms in the surface heat and momentum fluxes.

A student-officer working under the direction of the PI used a mixed layer model developed by Roland Garwood to examine the sensitivity of the ocean to various atmospheric forcing scenarios. The model predictions after one month were very similar to the what was observed in the ocean with the CTD profiles, giving confidence in the ability of the model to correctly simulate ocean responses to the atmoshere.

SCIENTIFIC/TECHNICAL RESULTS

The 1997 *Knorr* cruise was characterized by high-magnitude atmospheric forcing. Sensible heat flux, latent heat flux, net longwave radiation and net shortwave radiation averaged -164 Wm^{-2}, -143 Wm^{-2}, -85 Wm^{-2} and 33 Wm^{-2} respectively, during the cruise. (Fluxes are defined as positive downward so negative values represent ocean cooling.) The total average heat flux, -357 Wm^{-2}, was two standard deviations higher than the climatological average for this region and season and represents one of the largest magnitude monthly-average ocean cooling for any ocean or season ever measured *in situ*. Wind stress was also large, averaging 0.274 Pa.

These fluxes had a profound effect on the ocean, causing the ocean mixed layer in one location to deepen from 400 m to 1500 m in a one-month period. The fluxes also contributed to deep atmospheric mixed (or boundary) layers, in one case 4.5 km high. These deep atmospheric mixed layers caused the atmosphere to have a high effective heat and moisture capacity with respect to surface fluxes because the heat energy and moisture were spread out over a large vertical area. As a result, the air temperature and humidity near the surface were not able to equilibrate with the ocean surface and the turbulent sensible and latent heat fluxes remained large throughout the Labrador Sea.

The ocean mixed layer numerical sensitivity studies showed that the integrated heat fluxes were more important than individual storms in determining ocean mixed layer depths and temperature/salinity characteristics. If the heat flux during the cruise period had been 75% greater than the observed values or if similar heat fluxes had occurred in December and January (which were relatively mild), then the ocean mixed layer would have extended down to 2000 m depth, which is the maximum depth achieved in the last ten years

IMPACT FOR SCIENCE/SYSTEMS APPLICATIONS

This work is primarily basic research, but there are some impacts and applications for the Navy and for science in general. This work should result in improved forecasts of the atmosphere and ocean in the Labrador Sea area. The knowledge gained by the PI is immediately transferred to US Navy Officers via a course on Polar Meteorology taught by the PI every year. Because deep convection has a role in controlling the global climate, this research may lead to a better understanding of how the Earth's atmosphere-ice-ocean will respond to increased "greenhouse gas" levels.

TRANSITIONS

None

RELATED PROJECTS

None

PUBLICATIONS

Guest, P.S., 1997: Marginal ice zone meteorology, in *IAMAS/IAPSO Earth-Ocean-Atmosphere, forces for change Abstracts*, edited by D. Jasper and T. Beeran, (an invited plenary address presented at the IAMAS/IAPSO joint assembly in Melbourne, Australia, 2 July) p. IP16-10.

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